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Legibility in Virtual Reality

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Background

Deaf and hard of hearing persons have difficulties understanding speech in noisy situations, or with many persons speaking

Project: Speech-to-text in Augmented Reality (AR). To create an AR aid that presents text in real time to deaf or people with hearing deficits. Conducted in collaboration with “The Swedish Association of Hard of Hearing People”

Virtual Reality (VR) used as method, instead of AR

Study of text presentation

Legibility and perception by the user

Eye tracking measurements for reading. Reading speed: approximation of legibility

Text legibility: - how clearly a reader can differentiate individual letters and words

- Readability: - the ease with which a reader can understand a written text

Many aspects have been studied for printed material:

Text size, line length, spacing etc.

May apply also to digital media

Research scope

Research questions:
The effects of text size, position in the field of view, and presentation style in VR on:
(1) text legibility,
(2) the user experience
(3) perception

Measures:
Eye metrics
Perceptual and behavioral measures

Text parameters

Text size
- Small, medium or large

Number of lines
- 1, 2 or 3

Position
- Above or below

Middle-layer
- None, gaussian blur or solid

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Experimental setup and design

Conducted at fraternity rooms of Uppsala University, Sweden

Conditions adjusted for Covid 19

- Face mask, hand washing, cleaning, distance etc.

HTC VIVE VR headset: Retrofitted Tobii eye trackers. Tobii Pro lab

Three sessions: A, B and C

Half of persons starts with A, other half with B

Session A : Search task

Session B: Reading and rating

Session C: Test persons select their own preferred settings

20 Participants: 12 males, 8 females, Age: 21 to 59 years

Group 1	Group 2
A	B
B	A
C	C

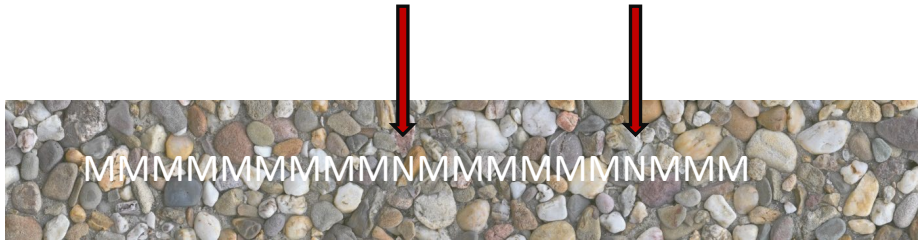
Session A

Search task

- Count the odd letters
- Randomly presented
  - between 1 and 3
- Decoys

Press button when done

- Verbal response



Session A - Variables

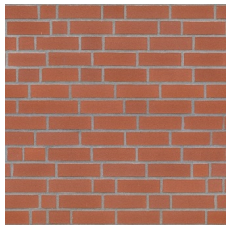
Independent variables – 60 conditions

- Text size (3 levels)
  - 7dmm, 14dmm and 21dmm
- Middle layer (4 levels)
  - None, Solid, Light and Strong blur
- Background (5 levels)
  - Argyle, bricks, ground, stripes, stones

Dependent variables

- Duration to complete (ms)
- Number of whole fixations
- Average fixation duration (ms)
- Average amplitude of saccades (deg)

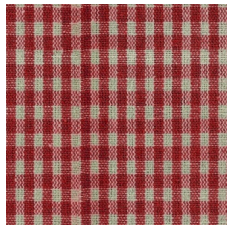
Argyle



Bricks

Ground

Stones



Striped

- Google: new font size unit: Distance-Independent Millimeter - dmm. Definition: height of the character of 1 mm at the distance of 1m.

Middle Layer: Example

NO MIDDLE LAYER

WITH MIDDLE LAYER

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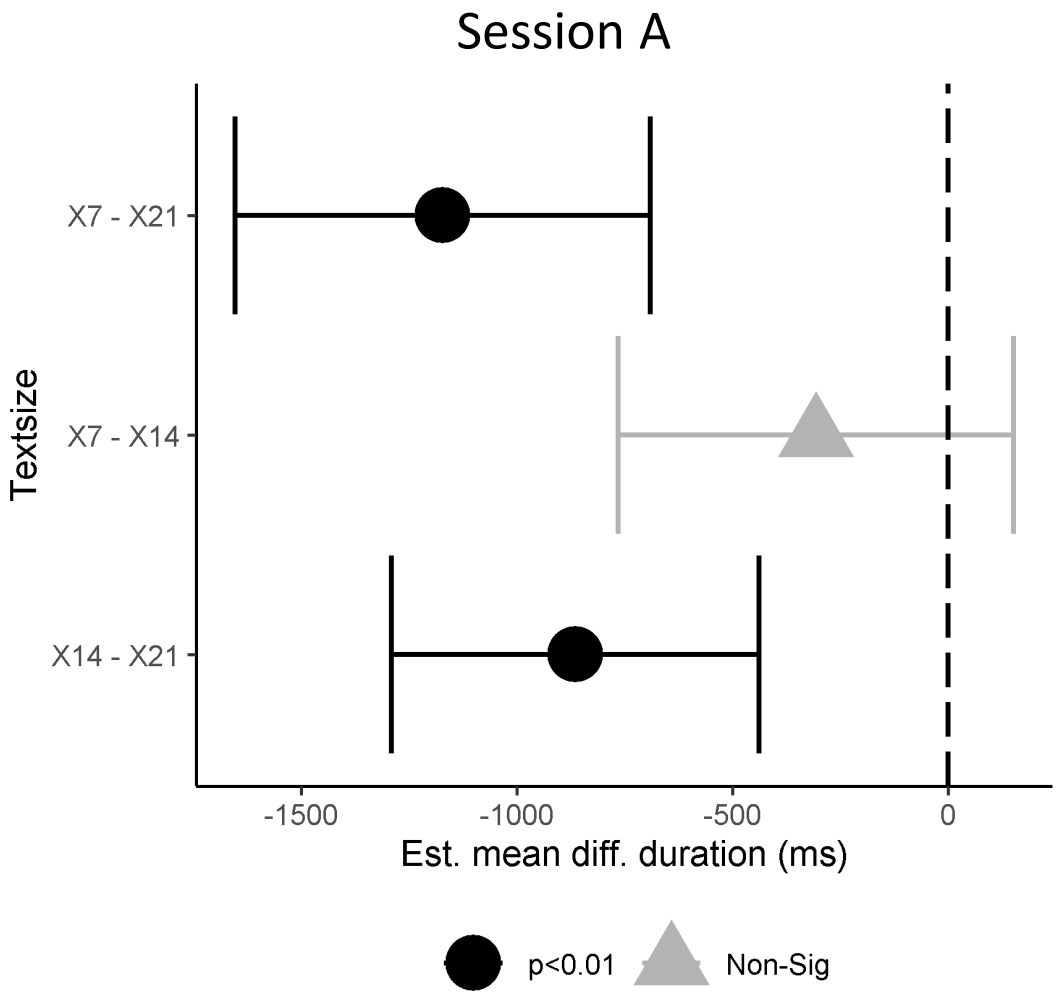
Duration – Size of text

Estimated difference of the different text sizes. (95% family confidence interval)

If the interval contains a zero it is not significant.

There is no significant difference between the small and medium text sizes 7dmm and 14dmm.

The large text, 21dmm, took on average 1s longer than the small or medium text.

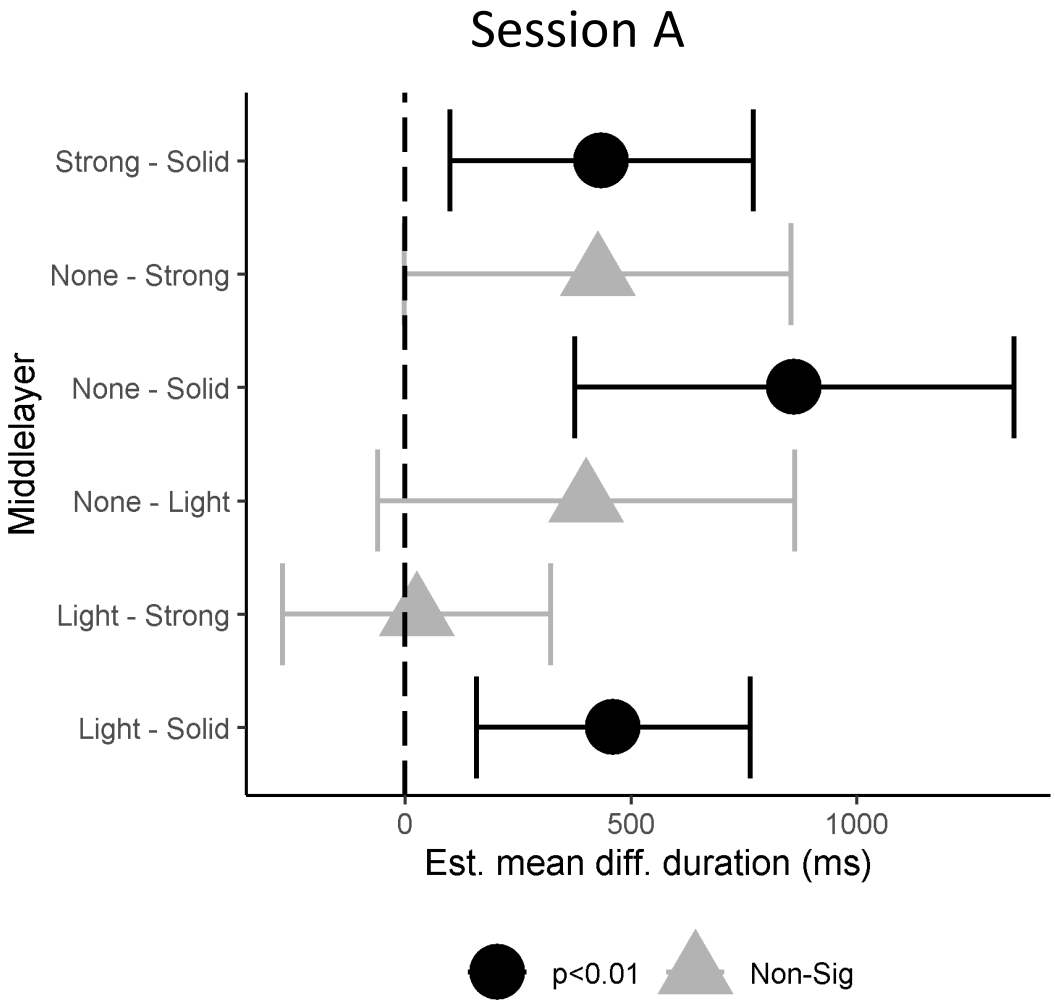


Duration – Middle-layer

No significant difference between blur and none.

Significant difference between the solid and the other middle-layers.

Reduces between on average 0.5 to 1s



Session A: Summary of results

Significant differences for all variables

Text size
- Large text took the longest time
- Large text required shorter but more fixations

Middle layer
- Only solid middle layer had a significant effect

Backgrounds
- Ground was more legible
  - Fewer and longer saccades
- Stones worse
  - More and shorter saccades

Better

Ground

Worse

Stones

Session B

Watch mute video

- Man talks about a Swedish furniture company
- Produced by the Swedish Public Employment Service
- 20s long
- Text presented (not shown here)

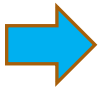
Session B: Variables

Independent variables – 54 conditions

- Text size (3 levels):
  - 11dmm, 16dmm and 21dmm
- Middle layer (3 levels)
  - None, Blur, Solid black
- Number of lines (3 levels)
  - 1, 2 or 3
- Position (2 levels)
  - Above or below speaker

Dependent variables

- Score given to three category scales
- Number of whole fixations
- Average fixation of duration (ms)
- Average amplitude of saccades (deg)



Category scales, 5 point scale

(1) “How legible was the text?” 1 =illegible, 5 =very legible
(2) “How comfortable was the text?” 1 = very uncomfortable, 5=very comfortable
(3) “Was the text in the way of the presentation” 1 = completely, 5 = not at all

Legibility – Position & Middle layer

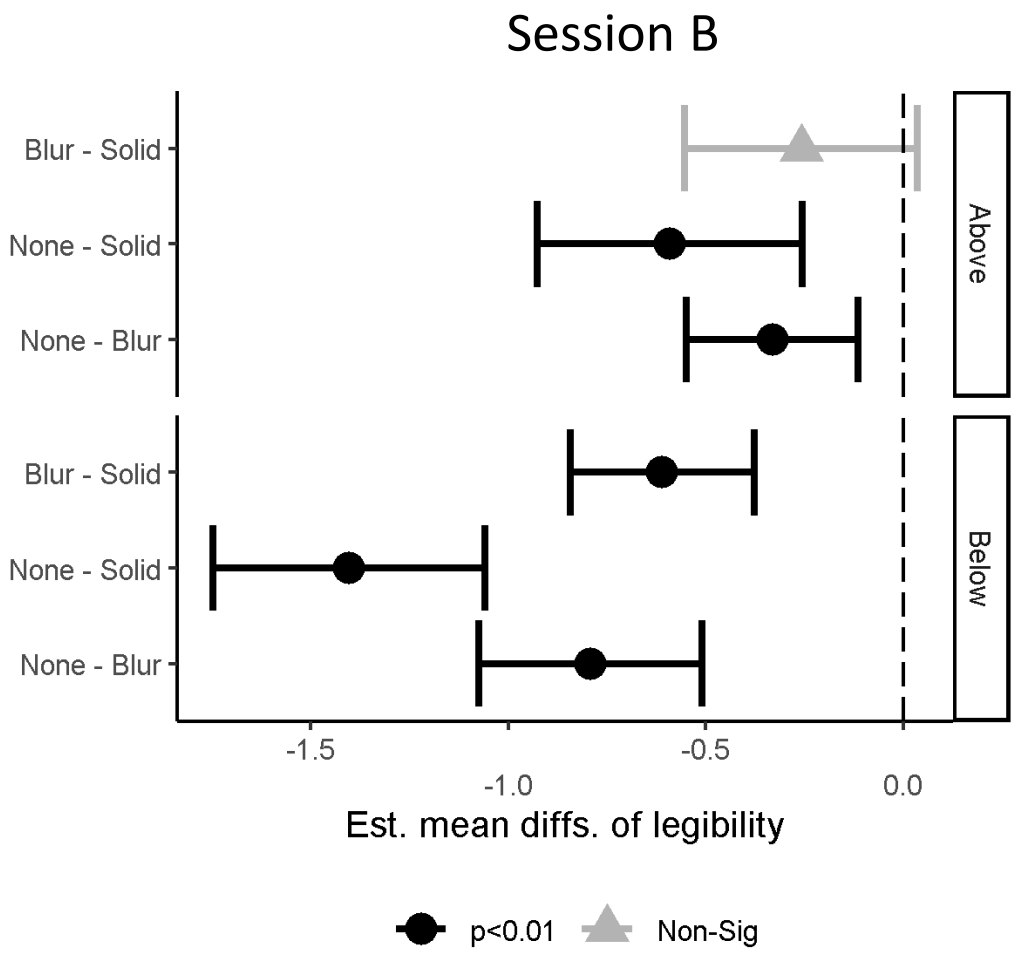
Above had higher legibility

Improves by around 0.5 points

Below had worse legibility

Improves almost 1.5 points!

Middle-layer have larger effect on already bad legibility

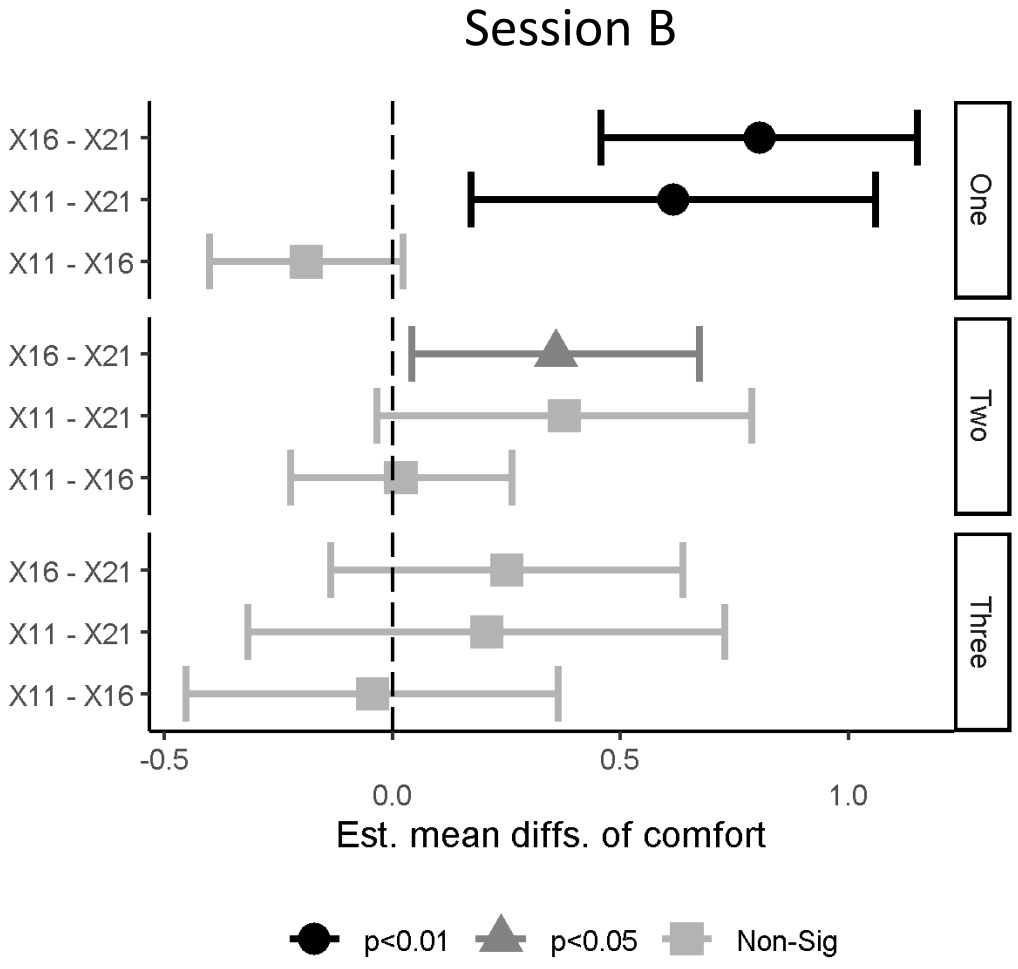


Comfort – Text size & Number of lines

Large text and one line bad

Combined large text and one line made a bad combination

Large and one line ~0.7 worse



Session B: Summary of results

Text size
- Largest text was less comfortable
- Obstruction increased with text size
- Smallest text had longer but fewer fixations.

Middle layer
- Improved comfort and legibility
- Both blur and solid reduced fixation duration
- Solid was in the way of the presentation

Number of lines
- 1 line – worse legibility and comfort
- 3 lines – in the way of the presentation

Position of text
- Above – better legibility
- Detached from the video

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Session C

Last session for all test persons

Utilize knowledge and preferences from previous sessions

Same video as in session B

Task: to set the most preferred setting for four variables

Same variables as in session B

- Text size
- Middle layer
- Number of lines
- Position

Session C: Summary of results

Large variations

Text size
- Between 7 and 21dmm
- Average 13.7 dmm

Middle layer
- 4 None, 10 Blur, 6 Solid black

Number of lines
- 6 One, 12 Two, 2 Three

Position
- 9 above
- 11 below

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Design recommendations:

Text size
- Not too big or too small
- Around 14dmm
    - DMM – Distance Independent Millimeter, 1 mm at 1 m distance

Middle layer
- Gaussian
    - If background should be visible
- Solid
    - If legibility is prioritized

Two lines of text

Position
- Below is probably preferred
- Case to case

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Thanks for your attention.

Research questions:

The effects of text size, position in the field of view, and presentation style on:
(1) text legibility, (2) the user experience and (3) perception?

Hypothesis for text on AR-devices:

1. Text size affects the legibility of the text.
2. Solid middle-layer will improve text legibility.
3. Solid middle-layer will obstruct the background behind it.
4. Gaussian blur middle-layer will improve text legibility.
5. Gaussian blur middle-layer will, to some extent, obstruct the background behind it.
6. More lines of text will offer a more comfortable reading experience than one line.
7. Users will prefer the text taking up as much space as possible, without obstructing areas of interest.
8. Users will prefer the text positioned as close to the areas of interest, without obstructing them.

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Eye metrics in this study

Average duration of fixations (ms)

Amplitude of saccades (deg)

Number of whole fixations

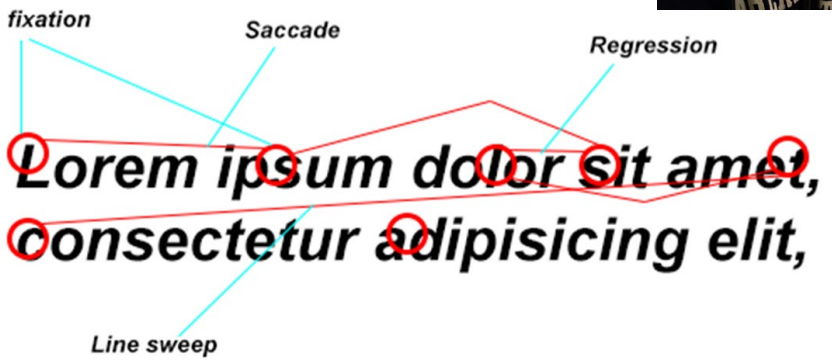
(Cannot differentiate types of saccades)

Measures of saccades in degrees

- Does not work for text sizes
- But works for other variables

Measure of number of fixations

- Influenced by saccade length and regressions



VR, AR and eye movements

Virtual Reality (VR)

- Simulation of senses and perceptual information
- Most often visual

Many different technologies

Augmented Reality (AR)

- Mixes information from real world with augmentations
- More variables to control

Eye movement measures for reading

- Higher detail at center of eye
- Continuous movement of the eyes
- Useful measure for reading processes
- Indicator of cognitive processes, e.g. attention, interest, boredom

Text Legibility

Text legibility - how clearly a reader can differentiate individual letters and words

Different from readability

- Content

Reading speed is an approximation of legibility

Many aspects have been studied for printed material

- Text size, line length, spacing etc.
- May apply also to digital media

Eye movement measures for reading

Higher detail at center of eye

Continuous movement of the eyes

Useful measure for reading processes

Indicator of cognitive processes, e.g. attention, interest, boredom

Example of findings:

Easier Text– Light Novel

- 200 ms fixations
- 9.2-character long saccades
- 365 words/minute

More difficult test– Biology Textbook

- 260 ms fixations
- 6.8 character long saccades
- 233 words/minute

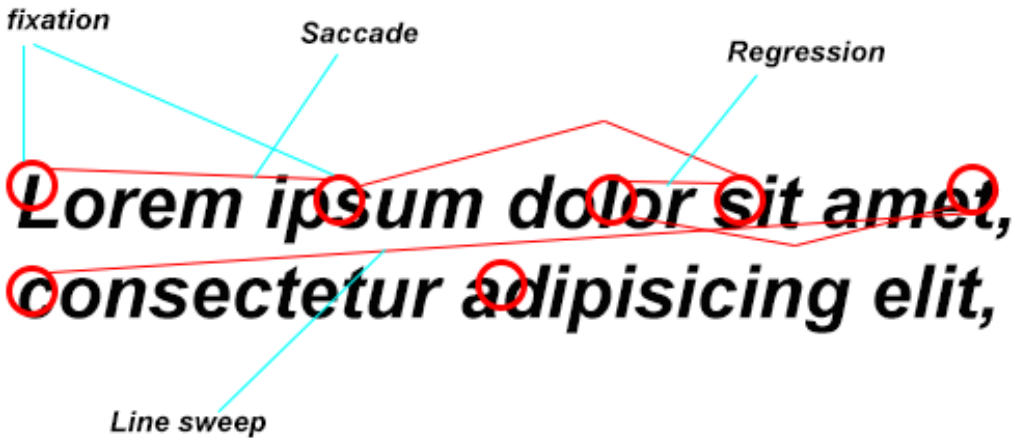
Eye movement metrics

Fixations
- Eye rest, fixates
- When we gather information
- 150 – 500ms

Saccades
- Movement between fixations
- No information gathered
- 7-9 characters long

Regressions
- Smaller type of backward saccade

Line sweeps
- Saccade from end of line



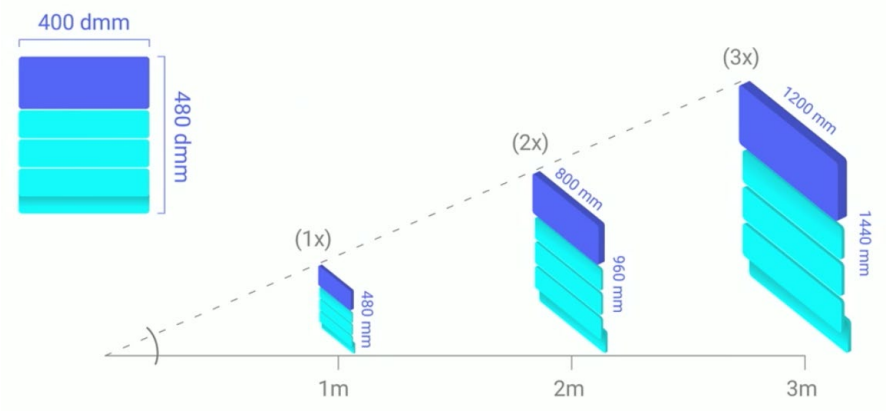
Text size

Typography
- Size on paper

Visual Science
- Angular size (size and distance)

DMM – Distance Independent Millimeter
- 1 mm at 1m distance
- 24dmm for body of text
  - Recommended by Google

Span of text size
- 3.5 to 35dmm



Experimental design

Three sessions
- A, B and C

Half of persons starts with A, other half with B

Session A
- Search task

Session B
- Reading and rating

Session C
- Test persons select their own preferred settings

20 Participants
- 12 males, 8 females
- Age: 21 to 59 years

Group 1	Group 2
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B	A
C	C

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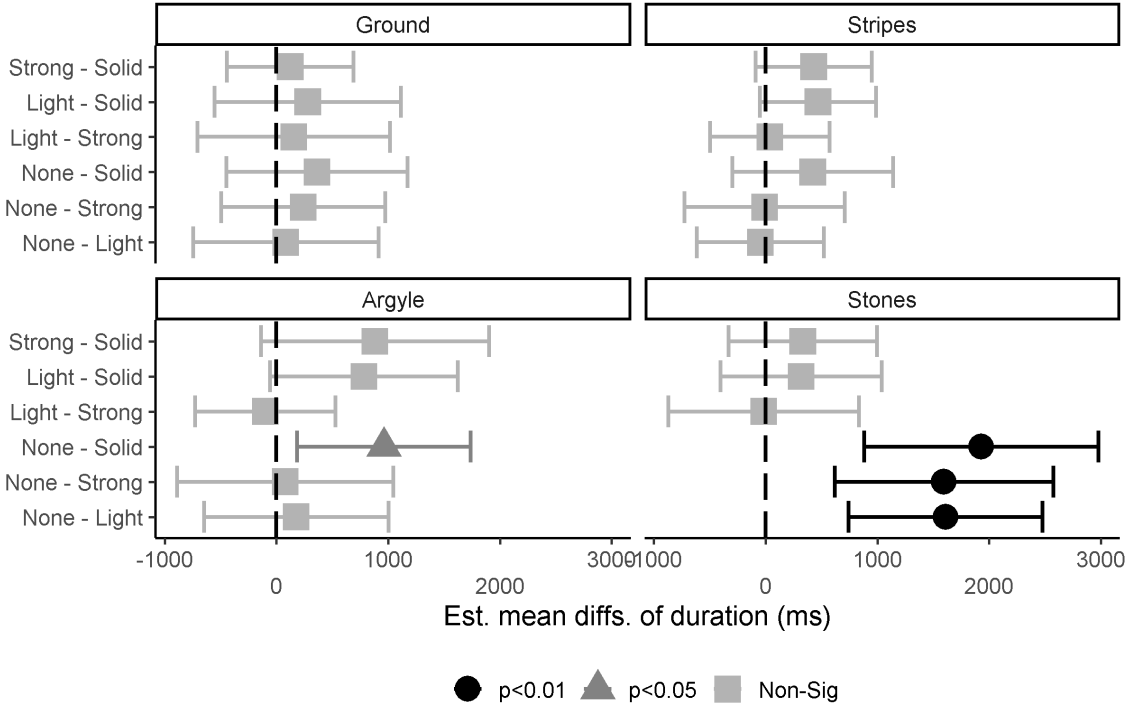
Duration – Background & Middle layer

No significant difference caused by the middle-layer except for stones and argyle.

When over complex backgrounds middle layers work better

Reduces on average by 2s.

Session A



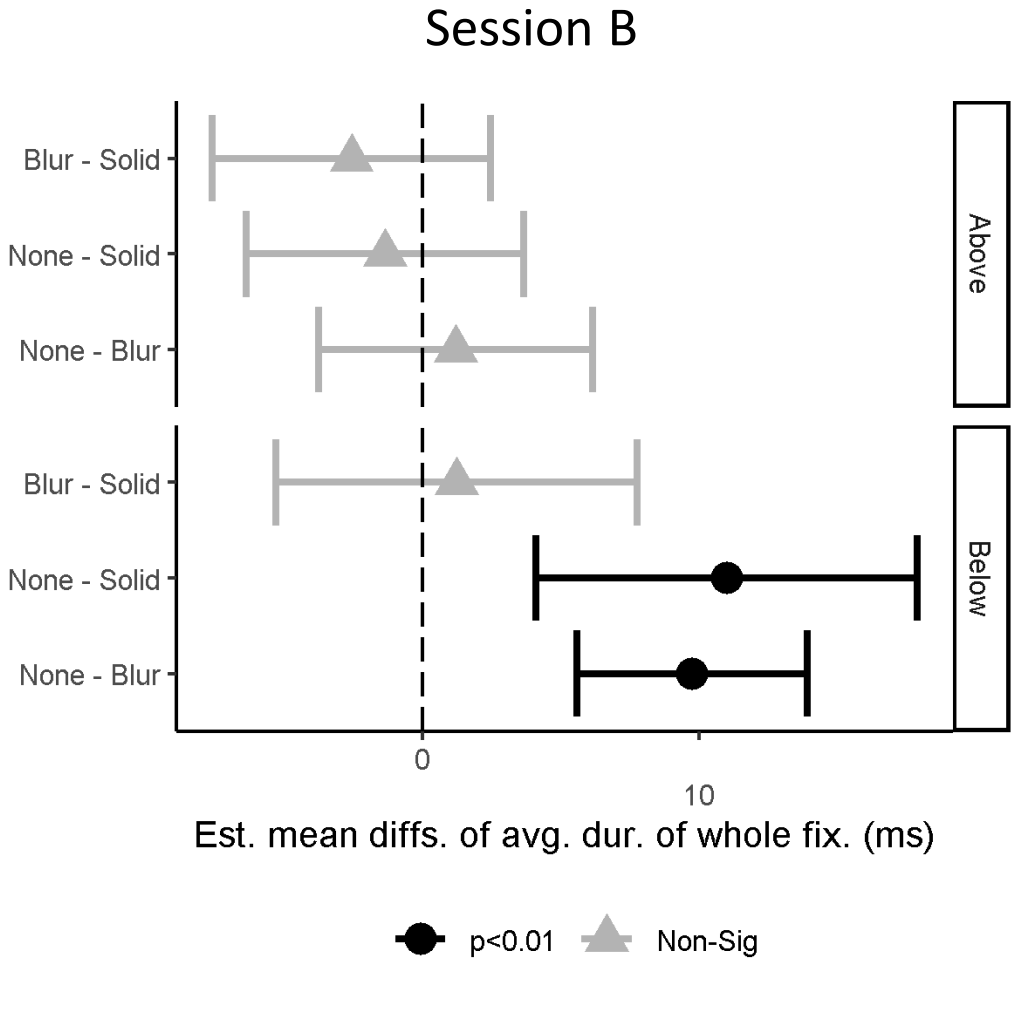
Fixation: Duration – Position & Middle layer

Same interaction

No significant effect when placed above

Reduces fixation duration by around 10ms and increase legibility

Present for number of fixations also



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